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Planning standards for v.h.f. and u.h.f. receiving aerial discrimination and height gains at domestic receiving locations

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PLANNING STANDARDS FOR VHF AND UHF RECEIVING AERIAL DISCRIMINATION AND HEIGHT GAINS AT DOMESTIC RECEIVING LOCATIONS

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Summary

This report summarizes the results of a limited investigation to study the validity of existing standards used in frequency planning of broadcast services for the protection afforded by the characteristics of receiving aerials against interfering transmissions. Although internationally agreed standards have been provided by the CCIR, some aspects of these CCIR standards are ambiguous.

An associated planning standard relating to assumptions about the variation of received signal with height of the receiving aerial above ground level is discussed in the Appendix to the Report.

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1. Introduction

CCIR Recommendation 419 provides planning standards for receiving aerial directivity protection at v.h.f. and u.h.f. as a function of azimuth angle between wanted and interfering transmitters. This standard applies to the case where the wanted and interfering transmissions have the same polarizations. CCIR Report 122-2 specifies values for the protection obtainable if wanted and interfering transmissions are orthogonally polarized. It is, however, not clear in the latter case whether the protections indicated for directivity and for orthogonal polarization should be considered as additive, particularly at v.h.f.

In order to assess in practical circumstance the combined effect of directivity and polarization discrimination a limited series of measurements have been carried out by the BBC in urban and surburban receiving locations. In view of the limited number of measurements it was not possible to include representative samples of all types of terrain. The majority of the measurements were made in Surrey and Essex and this may not be fully representative of the more rugged terrain in other parts of the United Kingdom. The u.h.f. results, however, covered a wider range of diffraction losses than those at v.h.f.

For television reception, planning is almost invariably based on the assumption that receiving aerials are fixed and at 10 a.g.l. but in Band II consideration has to be given to reception on car radios and portable receivers and for assessing possiblities of interference to mobile services operating in the same and immediately adjacent band. In CCIR Rec. 370-3 it is suggested that receiving aerial height gains from 3 m to 10 m a.g.l. are dependent upon the length of the propagation path, values for path lengths greater than 100 km being only half these for paths less than 50 km in length. Measurements carried out to test the veracity of this assumption are described and discussed in Appendix I to this report.

It should be emphasized that the work described in this report is not concerned with the performance of aerials with a well controlled test signal, but with the combined effect of propagation and aerial characteristics in practical situations. Except in the case of Band III, for which a comparison was made between yagi and log-periodic aerials, no particular attempt was made to compare the performances of different types of receiving aerial. Nor was any attempt made to assess the variation in performance of the aerials used over the band for which they were designed, the choice of frequencies being determined by practical considerations.

2. Test Procedure

Measurements of receiving aerial discrimination were made within the service areas of broadcast transmitters, an attempt being made, in so far as possible with a somewhat limited number of measurements, to choose a representative sample of receiving locations. At each location the aerial was rotated through 360° while elevated to 10 m a.g.l. and the results recorded on an X-Y plotter. These plots were taken with the aerial in both the same and the orthogonal plane of polarization as the transmitted signal, which for this purpose was considered to represent an interfering source.

The total number of plots obtained and the aerials used are given in Table 1. Two different types of aerial were used for tests in Bands II and III.

3. Results

The results of the measurements were analysed at 10° intervals of azimuth and the results are shown in Figs 1 - 16.

In view of the large differences between the results of the two polarizations in the v.h.f. bands these results are shown separately. Conversely the difference between results for horizontal and vertical polarizations at Bands IV and V were small and the results have been combined. In the case of Band II, measurements could be made only on horizontally polarized transmissions and obtained only for horizontally polarised aerials*.

* Apart from Eire the use of vertical polarization in Band II is exceptional. This Band does, however, present another exceptional discrimination condition as a consequence of the increasing use of mixed polarized transmissions. This aspect is not considered in this report.

Table 1

Number of samples

Band	Polarization of transmission	Receiving aerial used	Number of samples
I	Horizontal Vertical	2 element yagi	22 22
II	Horizontal	2 element yagi 3 element yagi	22 22
III	Horizontal Vertical	5 element wide-band yagi	20 20
III	Horizontal Vertical	5 element log-periodic aerial	20 20
IV	Horizontal	10 element yagi	21

Measured horizontal radiation patterns of the aerials used are superimposed on the Band I (Figs. 1 and 3) and Band IV/V figures (Fig.15). In both cases the median measured value of discrimination corresponds closely to the measured h.r.p. except that at u.h.f. the maximum value of the median (50%) discrimination appears to be about 15 or 16 dB to the effect of clutter and scattering.

4. Discussion

4.1. General

The primary purpose of this investigation was to examine the protection ratio standards adopted when the interfering station is orthogonally polarized i.e., what is termed polarization discrimination in this report. However, it is relevant also to examine how the results for the same polarization (termed directivity protection) relate to the long-established standards represented in CCIR Rec. 419, since it is logical that the same standards of protection be applied in both cases. Deducing standards for polarization discrimination by comparison with those for directivity protection will to some extent compensate for the fact that only a limited amount of measurement data is available.

4.2. Aerial Directivity Protection (Figs. 1, 3, 5, 6, 7, 8, 9, 10 and 15)

4.2.1. Bands I and II

a) For horizontally polarized transmissions (Figs. 1, 5 and 6) the directivity protection of CCIR Rec. 419 is exceeded at more than 90% locations. With 2-element aerials the protection achieved is, as may be expected, best when relative bearings of wanted and interfering transmissions are approximately 90°.

For the 3-element Band II aerial the protection achieved at 90% of locations is virtually independent of relative bearing at angles > 80° and is substantially better than implied by CCIR Rec. 419. In this context it is relevant to note that there is general support within the EBU for the proposal that in planning for stereophonic reception in Band II and, on the assumption that listeners should if necessary be prepared to use a 3-element receiving aerial, the Band III curve of CCIR Rec. 419 should be used for planning in preference to the Band I/II curve. The results represented in Fig. 6 support this proposal except between relative bearings 30° - 60° indicating that, except over this arc, the required additional protection may well be achieved without recourse to more than a 2-element aerial.

b) for vertical polarization (Fig.3) the

*ARD/ZDF in a contribution to EBU Working Party Sub-group R-1.

directivity protection achieved even at 50% locations falls short of the CCIR standard over the arc 60° - 90°, although the CCIR standard is obtained for 90% of locations at relative bearings ⩾120°.

It will, however, be appreciated that CCIR Rec. 419 represents a compromise applicable to both polarizations. The differences between the results in Figs. 1 and 3 emphasize the limitations of such a compromise, which would presumably have applied also for Band II had results been obtained for vertical polarization.

4.2.2. Band III

a) For horizontal polarization (Figs. 11 and 12) the yagi and log-periodic aerials had very similar performances except over the arc 150° - 180° where the latter met the CCIR standard at 90% of locations* whilst the former did not. Neither aerial quite achieved the CCIR standard at 90% locations over the arc 30° - 70°. As with the 2-element aerials at Bands I/II protection is greatest at relative angles of about 90° - 100°.

b) For vertical polarization (Figs. 7 and 8) the yagi aerial failed to meet the CCIR standard even for 50% locations over a substantial arc. The log-periodic aerial was better although still failing to achieve the CCIR standard over the sector 30° - 100°, but exceeding it at 90% locations for bearings > 100°.

Whereas the extent to which the Band III directivity protection curve of Rec. 419 over-estimates the protection afforded at 90% locations is small in the case of horizontal polarization (Figs. 11 and 12) the discrepancy for vertical polarization appears to be sufficiently serious to justify the use of a different curve for this condition. A curve in which the protection increases linearly with azimuth from 0 dB at 40° to a maximum of 12 dB at 130° would seem to be an appropriate compromise based on Figs. 7 and 8.

4.2.3. Bands IV/V

As previously stated, the u.h.f. results for both horizontal and vertical polarizations have been combined to form Fig. 15. Both the curve of CCIR Rec. 419 and the slightly different curve currently used as a planning standard by the BBC correspond closely to the median value of measured directivity protection. Values of protection achieved at 90% of locations are about 8 dB lower than the median value at relative bearings exceeding about ± 40°

* As an additional test the log-periodic aerial was also tested under the condition in which the outer braiding of the co-axial feeder was electrically bonded at one point to the aerial boom (to which it was strapped). This was found to improve the directivity pattern significantly (⩾ 18 dB protection being achieved for 90% locations at relative bearings > 70°). It is, however, unlikley that this extra precaution would be taken under normal domestic installation conditions.

4.3. Polarization discrimination

4.3.1. Band I*

Discrimination when the wanted transmission is horizontally polarized (Fig.4) appears somewhat greater than when it is vertically polarized (Fig. 2). In both cases there is some evidence to support a planning standard in which discrimination varies with azimuth (see section 4.3.3.) although this is more apparent in the case of Fig.4 than in Fig. 2.

4.3.2. Band III

In this Band there appears to be a definite correlation of discrimination with azimuth when the wanted signal is horizontally polarized (Figs. 9 and 10) but little or no correlation when it is vertically polarized (Figs. 13 and 14). Unlike the case of Band I (Section 4.3.1.) the difference between the two polarizations in Band III seems sufficiently great as to justify the use of different planning standards for the two polarizations.

4.3.3. Bands IV/V (Fig. 16)

As with directivity protection (Section 4.2.3.) the results for both polarizations have been combined. There appears to be a small variation in discrimination with relative angle. In this respect the results fall between the current planning standard used by the BBC, (15 dB at all relative bearings) and that of the "UK proposal" of CCIR Report 122-2. This "UK proposal", which is based on previous work, is reproduced in Appendix 3.

A suitable compromise would seem to be to adopt a value for discrimination increasing linearly with relative bearing from 14 dB at 0° to 20 dB at 180°. This corresponds fairly well to the variation of measured discrimination obtained at

* No results could be obtained for Band II, but it is not expected that vertical polarization will be adopted in this Band within the United Kingdom. Polarization discrimination is, of course, inapplicable in the case of mixed polarized transmissions having comparable magnitudes of signal in both horizontal and vertical planes.

50% locations.

Such a value would also appear to be a suitable planning standard (for 90% locations) in Band I (See Figs. 2 and 4). It might also be accepted as a reasonable compromise for Band III (See Figs. 9, 19, 13, 14) if it is not considered worthwhile adopting different standards for horizontal and vertical polarizations.

5. Conclusions

i) The results indicated that the directivity protections implied by CCIR Rec. 419 are achieved at a considerably greater percentage of locations in the v.h.f. bands than at u.h.f.

ii) Unless therefore it is considered desirable to adopt different standards for directivity protection from those of CCIR Rec. 419 in order to elimate this anomaly it would seem sensible to adopt corresponding standards (90% locations at v.h.f., 50% locations at u.h.f.) for polarization discrimination.

iii) At u.h.f. the results for polarization discrimination appear to fall between those currently used by the BBC (which assume no variation with azimuth) and those of CCIR Report 122-2 (which show a considerable variation).

A suitable compromise would seem to be to adopt a standard in which the protection ratio increases linearly with relative bearing from 14 dB to 20 dB. However, it seems questionable whether it is, in practice, worth changing to a new standard for u.h.f. planning within the U.K. at this stage of development of the u.h.f. television network.

iv) A polarization discrimination increasing linearly with bearing from 14 dB to 20 dB also seems appropriate for Band I. It could also reasonably be applied to Band III if, for simplicity, it were not considered worthwhile adopting different standards according to the polarization of the wanted signal.

Should, however, it be considered that the difference between the results for the two polarizations at Band III are sufficient to warrant the use of different standards* it is proposed that:

a) for horizontal polarization of the wanted signal the discrimination be taken by adding the directivity of Rec. 419 to a basic polarization discrimination of 8 dB.

b) for vertical polarization an 18 dB discrimination (the CCIR Report 122-2 value for 50% locations) be considered to apply at all azimuths.

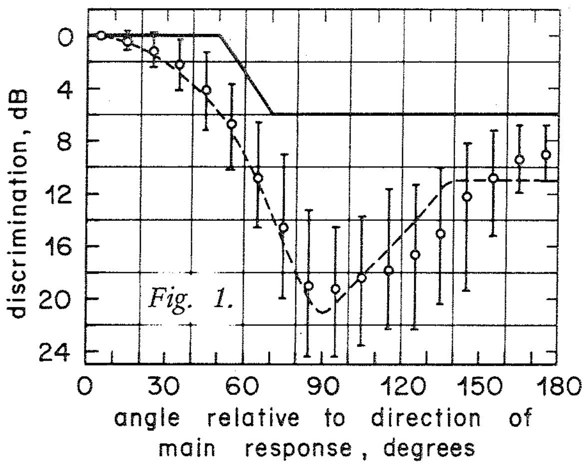
vi) Bearing in mind that, at least within the U.K., Band III is likely to be of greater importance than Band I for future television development it seems preferable to ensure that the planning parameters for Band III conform as well as possible to measurement data, rather than to seek a simple compromise solution to both Bands.

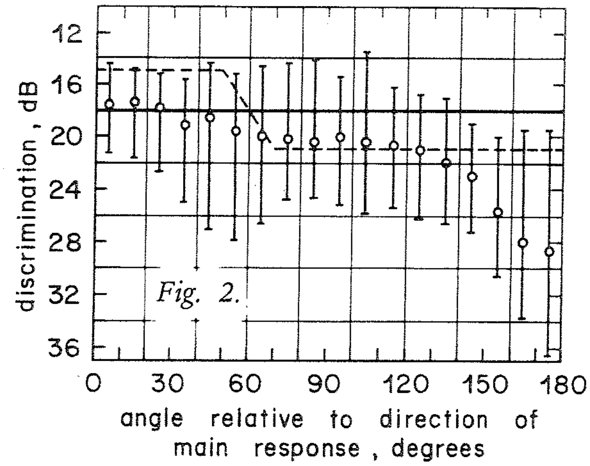
vii) As discussed in Section 4.2.2. the directivity protection curve for Band III in CCIR Rec. 419 would seem to seriously overestimate the protection afforded in the case of vertically polarised transmissions. It is recommended that a different curve be used for this condition having a protection increasing linearly with relative bearing from 0 dB at 40° to a maximum of 12 dB at 130°. The existing curve would be retained in the case of horizontal polarization.

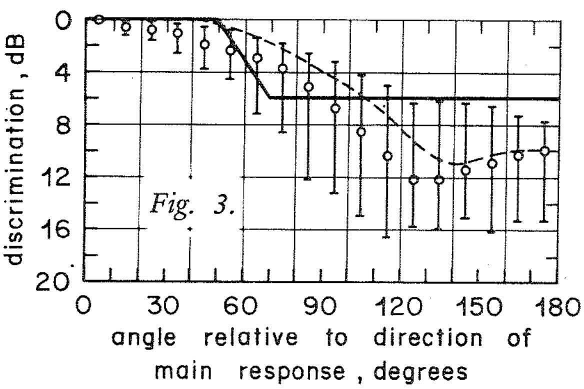
If agreed that different directivity protection curves be used for vertical and horizontal polarization this strengthens the case for differing standards for polarization discrimination also (see para iv).

viii) For Band II, lack of measurements preclude any recommendations on polarization discrimination. The situation in this Band is complicated by the use of mixed polarized transmissions, and the fact that, for reception on portable receivers and car radios, the receiving aerial is generally vertically polarized irrespective of the polarization of the transmission. It is however recommended that planning for directivity protection be on the basis of the Band III curve of Rec. 419. Directivity protection should only be taken into account in planning of stereophonic services, on the basis that most monophonic reception is on portable receivers and car radios.

*See the following para (vii)







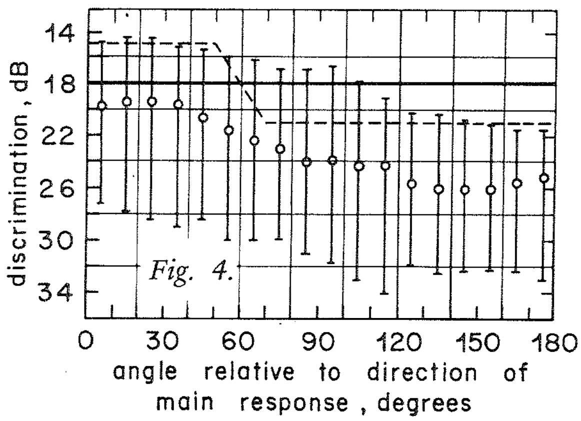


Fig. 1. Receiving aerial discrimination Band I: Same Polarization.

Unwanted transmission, Horizontally polarized. (Receiving aerial: Horizontally polarized.)

——— CCIR Rec. 419 — — — Measured h.r.p.

Fig. 2. Receiving aerial discrimination Band I: Orthogonal Polarization.

Unwanted transmission, Horizontally polarized. (Receiving aerial: Vertically polarized.)

——— CCIR Rep. 122-2 for 50% location — — — 15dB polarization discrimination plus directivity discrimination of CCIR Rec 419

Fig. 3. Receiving aerial discrimination Band I: Same Polarization.

Unwanted transmission, Vertically polarized. (Receiving aerial: Vertically polarized.)

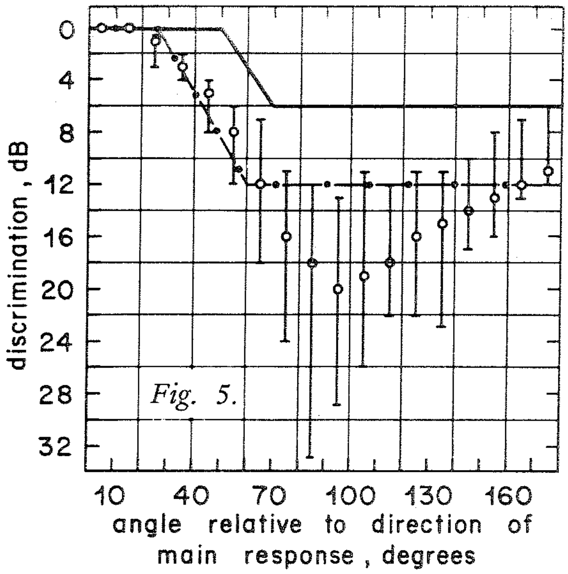
——— CCIR Rec. 419 — — — Measured h.r.p.

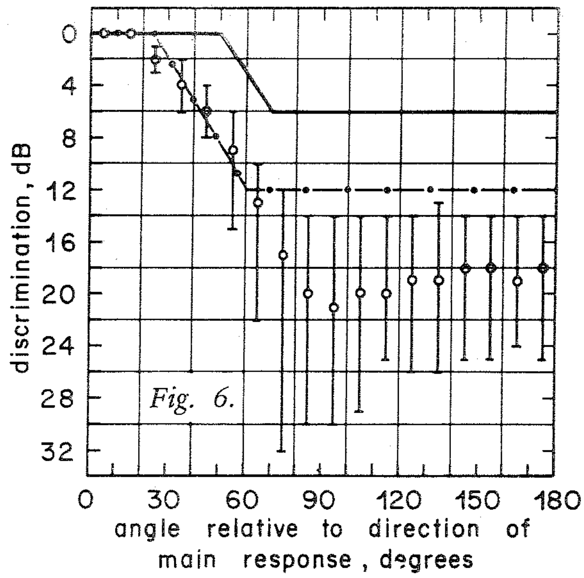
Fig. 4. Receiving aerial discrimination Band I: Orthogonal Polarization.

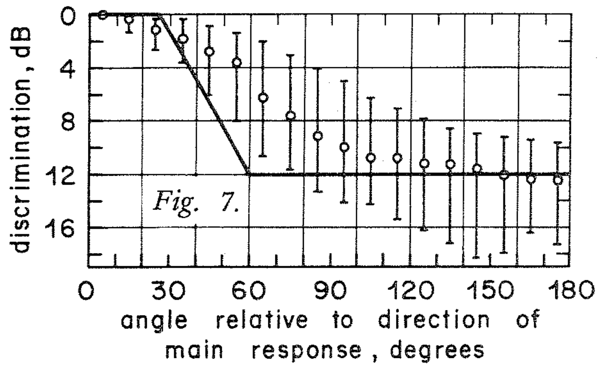
Unwanted transmission, Vertically polarized. (Receiving aerial: Horizontally polarized.)

——— CCIR Rep. 122-2 for 50% locations — — — 15dB polarization discrimination plus directivity discrimination of CCIR Rec 419

90% Measured discrimination
50% at percentage of
10% locations indicated.







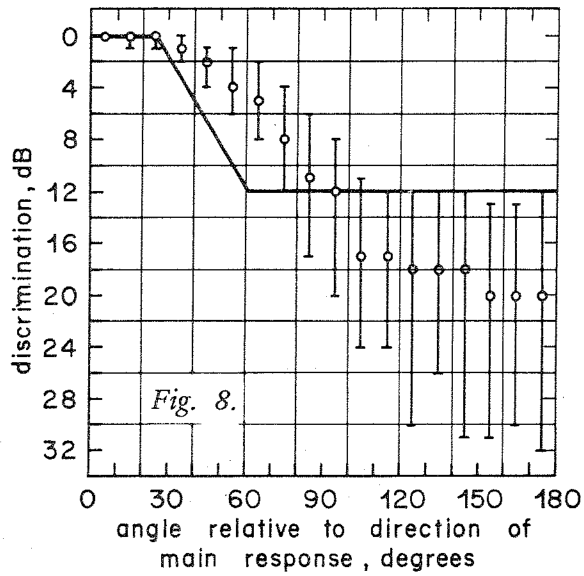


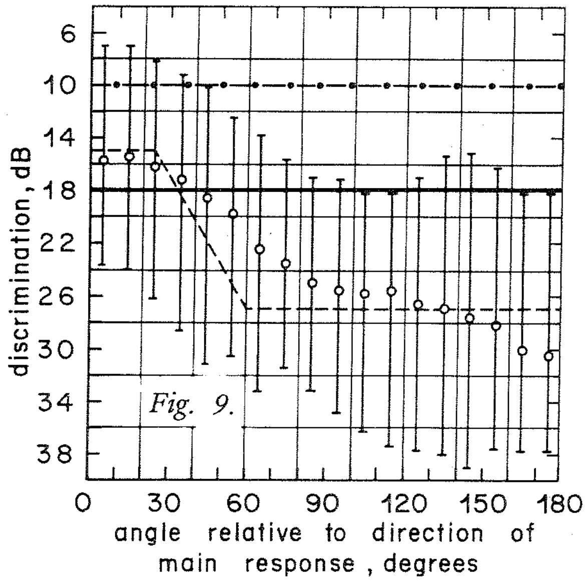
Fig. 5. Receiving aerial discrimination Band II: Same Polarization.
Unwanted transmission, Horizontally polarized. (2-element receiving aerial: horizontally polarized.)
——— CCIR Rec. 419 for Bands I and II   •—•— CCIR Rec 419 for Band II

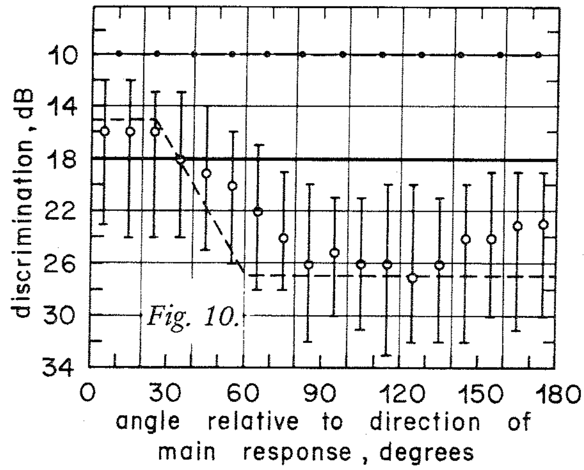
Fig. 6. Receiving aeral discrimination Band II: Same Polarization.
Unwanted transmission, Horizontally polarized. (3-element receiving aerial: Horizontally polarized.)
——— CCIR Rec. 419 for bands I and II   •—•— CCIR Rec 419 for Band III

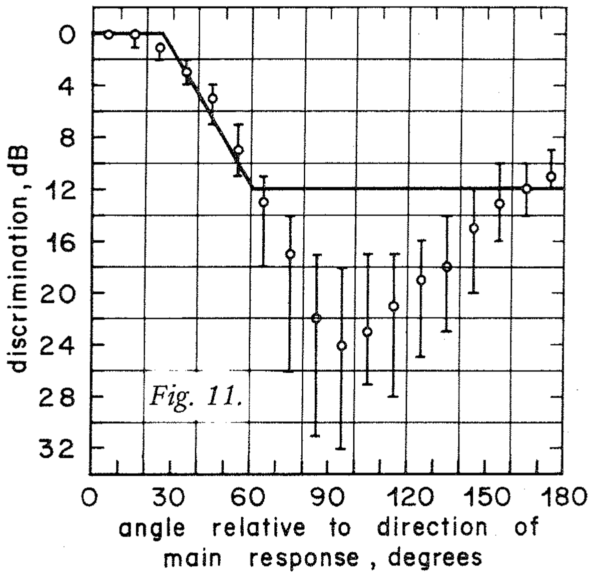
Fig. 7. Receiving aerial discrimination Band III: Same Polarization.
Unwanted transmission, Vertically polarized. (5-element yagi receiving aerial: Vertically polarized.)
——— CCIR Rec. 419

Fig. 8. Receiving aerial discrimination Band III: Same Polarization.
Unwanted transmission, Vertically polarized. (5-element log-periodic aerial: Vertically polarized.)
——— CCIR Rec. 419

90 % Measured discrimination
50 % at percentage of
10 % locations indicated.







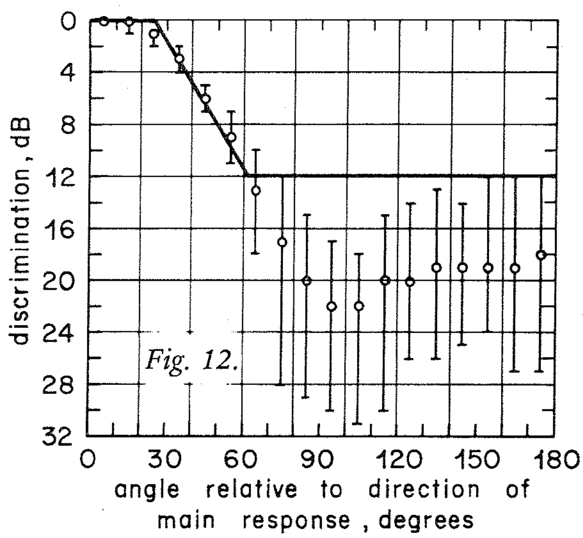


Fig. 9. Receiving aerial discrimination Band III: Orthogonal Polarization.

Unwanted transmission, Vertically polarized. (5-element yagi receiving aerial: Horizontally polarized.)

•—•— CCIR Rep 122-2 for 10% locations ——— CCIR Rep 122-2 for 50% locations

- - - - 15dB polarization discrimination plus directivity discrimination of CCIR Rec 419

Fig.10. Receiving aerial discrimination Band III: Orthogonal Polarization.

Unwanted transmission, Vertically polarized. (5-element log-periodic aerial: Horizontally polarized.)

•—•— CCIR Report 122-2 for 10% locations ——— CCIR Report 122-2 for 50% locations

- - - - 15dB polarization plus directivity discrimination of CCIR Rec 419

Fig.11. Receiving aerial discrimination Band III: Same Polarization.

Unwanted transmission, Horizontally polarized. (5-element Yagi aerial: Horizontally polarized.)

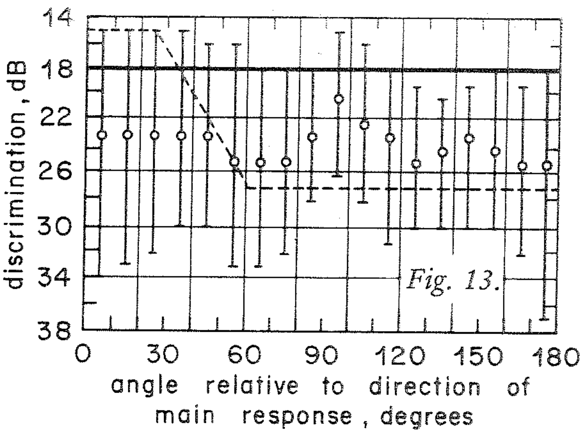
——— CCIR Rec 419

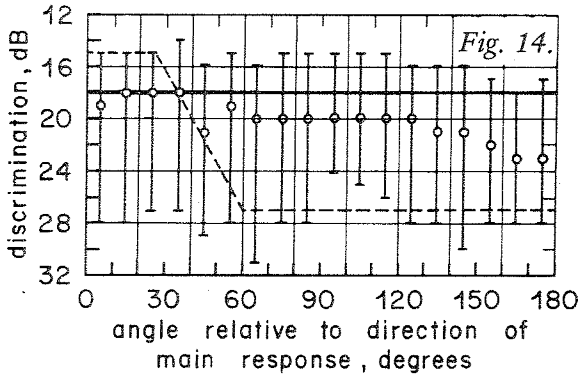
Fig.12. Receiving aerial discrimination Band III: Same Polarization.

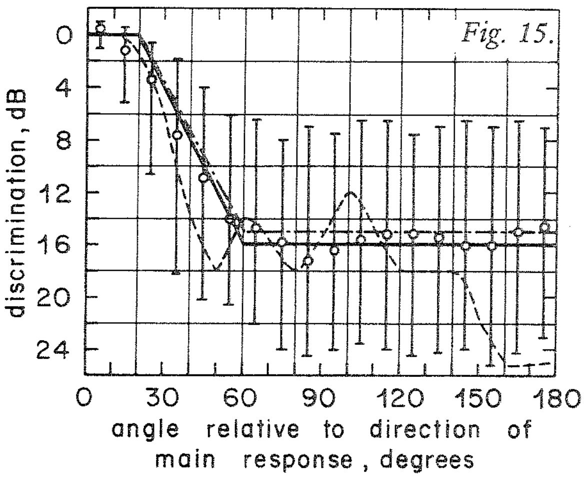
Unwanted transmission, Horizontally polarized. (5-element log-periodic aerial: Horizontally polarized.)

——— CCIR Rec 419

90 % Measured discrimination
50 % at percentage of
10 % locations indicated.







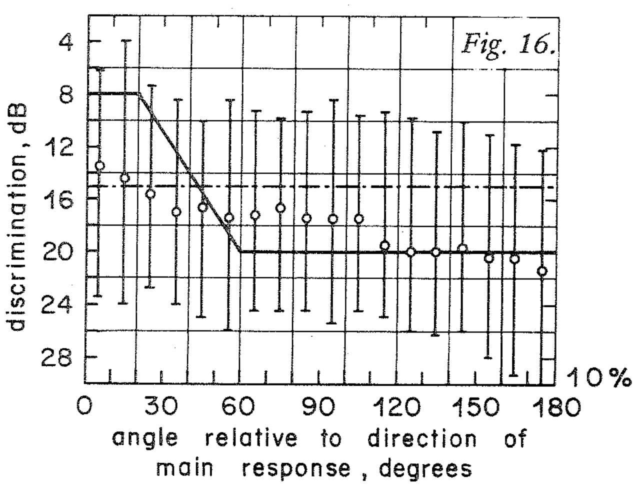


Fig.13. Receiving aerial discrimination Band III: Orthogonal Polarization.

Unwanted transmission, Horizontally polarized. (5-element Yagi aerial: Vertically polarized.)

——— CCIR Report 122-2 for 50% locations – – –15dB polarization discrimination plus directivity discrimination of CCIR Rec 419

Fig.14. Receiving aerial discrimination Band III: Orthogonal Polarization.

Unwanted transmission, Horizontally polarized. (5-element log-periodic aerial: Vertically polarized.)

——— CCIR Report 122-2 for 50% locations – – –15dB polarization discrimination plus directivity discrimination of CCIR Rec 419

Fig.15. Receiving aerial discrimination Bands IV and V: Same Polarization.

——— CCIR Rec 419 – – – – Measured h.r.p.

• – • – Current Planning Standard used by the BBC

Fig.16. Receiving aerial discrimination Bands IV and V: Orthogonal Polarization.

——— CCIR Rep. 122-2 ('UK Proposal') • – • – Current Planning Standard used by the BBC

90% Measured discrimination
50% at percentage of
10% locations indicated.

Appendix 1

RECEIVING AERIAL HEIGHT GAINS IN BAND II

1. Introduction

CCIR Recommendation 370-3 gives information on expected values of receiving aerial height gains. For Bands I and II Para. 6 of Annex I to the Recommendation states that:-

"The following median values of gain may be expected in changing the receiving antenna height from 3 m to 10 m above ground level; in Bands I and II, 9 dB in hilly or flat terrain for both urban and rural areas .... These values apply for distances up to 50 km. For distances in excess of 100 km the values should be halved with linear interpolation for intermediate distances".

Similar information is also given in CCIR Report 567-1.

In the past these assumptions about height gain have been of little interest in broadcast network planning since this has assumed receiving aerials to be at 10 m a.g.l. The above section of Rec. 370 was, however, included in the Technical Criteria of the Darmstadt Plan because of the need to protect mobile services sharing the band covered by this Plan.

If, however, the forthcoming Band II Regional Conference should decide to plan for both stereophonic and monophonic reception it may well also be decided that the latter should be planned on the basis of reception with portable receivers and car radios. In this case the receiving aerial would be assumed to be lower than 3 m a.g.l. and, since the wanted transmitter will generally be much closer than interfering transmitters, additional protection would be required to offset any assumed systematic variation of height gain with path length*.

2. Basis of measurements

In order to investigate this relationship a series of receiving aerial height gain measurements was made during the course of a survey of a local radio station. At each point visited, height gains from 3 m to 10 m a.g.l. were noted both for the station being surveyed** and for a "distant" station more than 100 km from the receiving point. Subject to satisfying this distance criterion the choice of distant station was determined solely by availability of adequate signal at 3 m a.g.l. It is accepted that this limitation might have introduced a bias into the results.

3. Results

Approximately 220 samples were available for both "local" and "distant" station height gains. The distributions were almost identical, the mean value being 10.1 dB for the "local" station and 10.0 dB for the "distant" station. In both cases 90% of the results were within ± 6 dB of the mean.

An analysis of the distribution of the ratio of local: distant station height gains obtained at each individual receiving location was also carried out. This gave a mean ratio of –0.1 dB, with 90% of samples within the range ± 10 dB.

4. Conclusion

The results of these measurements give no support to the suggestion in CCIR Rec. 370-3 that receiving aerial height gains are correlated to propagation path length. Moreover it had previously been the practice to carry out coverage surveys of BBC v.h.f. radio stations by making field strength measurements at approximately 3 m a.g.l., correcting to 10 m a.g.l. by assuming field strength to increase in direct proportion to height. These surveys have subsequently been repeated with measurements made at 10 m. There is no evidence that the earlier surveys have systematically over-estimated coverage despite the fact that some stations have service ranges in excess of 100 km.

It is therefore suggested that for planning purposes it be assumed that receiving aerial height gains are independent of path length.

* The reference field strength being that at 10 m a.g.l.

** For the great majority of measurements these path lengths were less than 50 km

Appendix 2

EXTENT OF VHF/UHF BROADCAST BANDS

		Remarks
Band I (television)	41 - 68 MHz	(1)
Band II (radio)	87.5 - 100 MHz	(2) (3)
Band III (television)	174 - 230 MHz	(4)
Band IV (television)	470 - 582 MHz	(5)
Band V (television)	606 - 854 MHz	(5)

Remarks

(1) Lower limit raised to 47 MHz by decision of WARC 1979

(2) Upper limit raised to 108 MHz by decision of WARC 1979

(3) Also used for television in Eastern Europe

(4) Upper limit raised to 230 MHz by decision of WARC 1979 (above 223 MHz unlikely to be available in U.K.)

(5) Some spectrum between 582 MHz and 606 MHz may become available in future.

Appendix 3

Extract from CCIR Report 122-2

2. Band 9 (UHF)

Experiments have been conducted in the United Kingdom to determine the polarization discrimination in band 9 (UHF) of receiving antennae at typical urban and rural sites. The results of measurements showed that for orthogonally polarized signals arriving in the direction of main response of the antenna, the discrimination obtained is similar to that already described above for frequencies in band 8 (VHF), although the factor exceeded for 90% of receiving sites was only 8 dB (as compared with 10 dB for band 8 (VHF)). In the case of discrimination against orthogonally polarized signals arriving within the arc 180° ± 90° relative to the direction of main response, measurements confirmed that at least 20 dB discrimination is achieved at 90% of receiving sites. As a result of these investigations, for television planning purposes in band 9 (UHF), the United Kingdom uses values of antenna discrimination for orthogonal transmissions which exceed the values for co-planar transmissions given in Recommendation 419, by 8 dB (total value: 8 dB) in the range of 0° to 20° relative to the direction of man response and by 4 dB (total value: 20 dB) in the range 60° to 180°. Linear interpolation is applies for the range 20° to 60° as in the existing curve for discrimination between co-planar transmissions.